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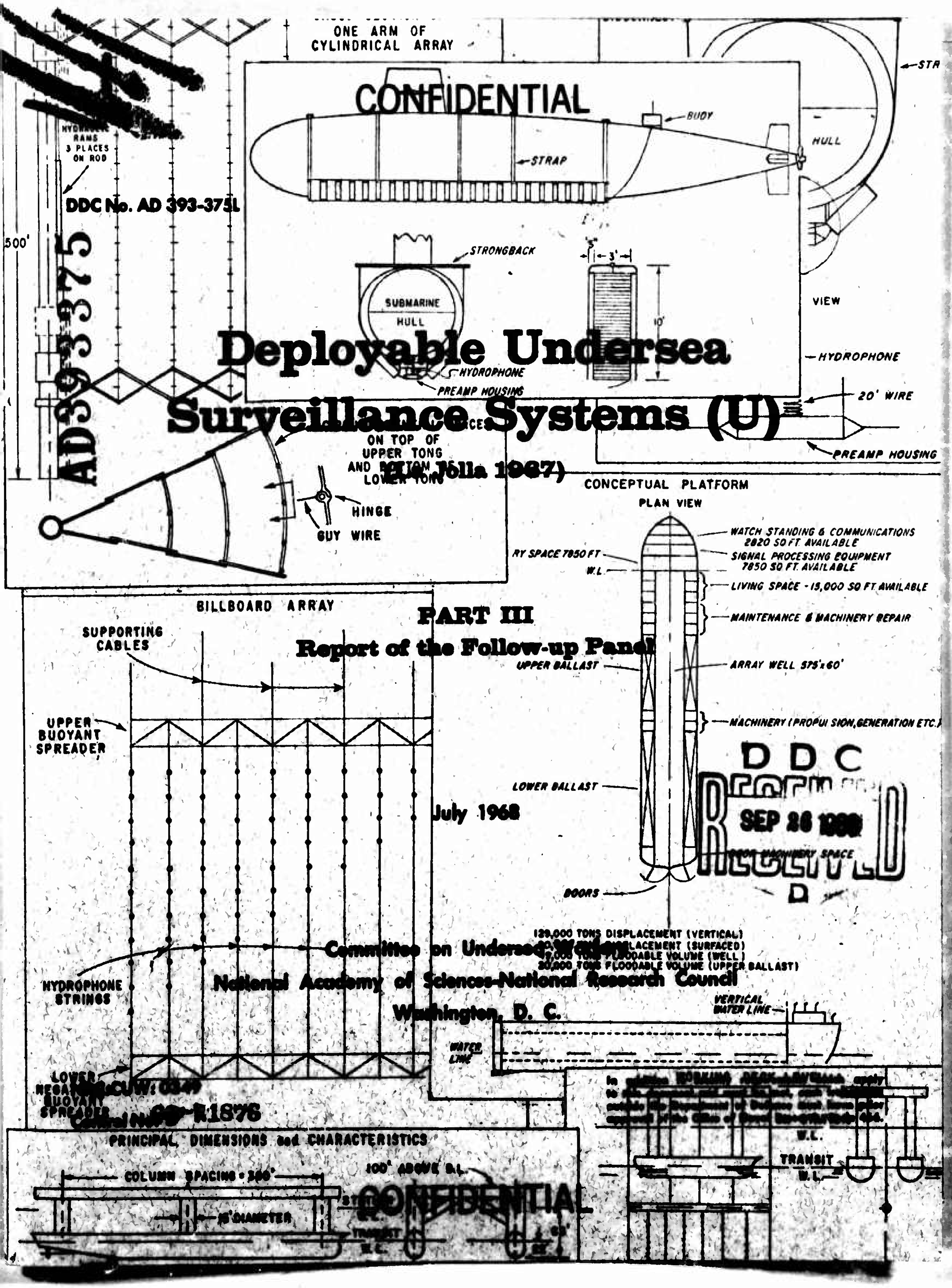

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Deployable Undersea Surveillance Systems (U)

(La Jolla 1967)

PART III

Report of the Follow-up Panel

July 1968

Committee on Undersea Warfare

National Academy of Sciences-National Research Council

Washington, D. C.

CUW: 0349

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DEPLOYABLE UNDERSEA SURVEILLANCE SYSTEMS (U)

(La Jolla 1967)

PART III

REPORT OF THE FOLLOW-UP PANEL

July 1968

Committee on Undersea Warfare
National Academy of Sciences-National Research Council
Washington, D. C.

NRC:CUW:0349

FOREWORD

The study of ocean surveillance sponsored by the Committee on Undersea Warfare commenced formally with the 1966 summer study at Woods Hole, Massachusetts. Although that effort considered the subject in broad terms, the need for further detailed investigation of deployable systems was recognized in a recommendation for an additional study the following summer.

As a result, a study of deployable undersea surveillance systems was undertaken in the summer of 1967 at La Jolla, California. A report[1] containing findings of this summer study has been forwarded to the Navy.

Because assistance was desired in relating the summer study conclusions and recommendations to the Navy's undersea surveillance research and development program, Rear Admiral E. W. Dobie, Jr., OP 71, requested[2] that the Committee form a small advisory group. The opportunity was welcomed by the Committee and at its 80th Meeting, July 1967, the establishment of a summer study follow-up panel was authorized.

In due course a panel composed of key participants in the summer study was organized with a membership which consisted of: Dr. Fred N. Spiess, Chairman, Director of the Marine Physical Laboratory, Scripps Institution of Oceanography; Dr. John C. Knight, Kettelle Associates, Inc.; Dr. Stanley Murphy, Applied Physics Laboratory, University of Washington; Mr. Henry A. O'Neal, Ocean Science and Technology Group, Office of Naval Research; Mr. Stanley A. Peterson, U. S. Navy Underwater Sound Laboratory; Mr. Benjamin Rosenberg, OP O7TC, Office of the Chief of Naval Operations; Mr. Leo M. Trietel, Code 2050, ASW Systems Project; Dr. Ross Williams, Hudson Laboratories, Columbia University; and Captain Jerome L. Wolf, OP715, Office of the Chief of Naval Operations; Mr. R. M. Chapman served as Panel Secretary.

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[1] NRC:CUW:0343 - "Deployable Undersea Surveillance Systems (U), (La Jolla 1967)", Part I, General Conclusions and Recommendations, December 1967. SECRET

[2] See Appendix A.

This report summarizes the deliberations of the Panel, conducted over the period from October 1967 through June 1968. During this time significant help was received from many quarters, particularly Mr. I. Gatzke and Dr. V. C. Anderson who met with the panel on several occasions. This report was edited by Mr. Chapman with assistance from E. H. Nelson, Jr. and the manuscript was prepared by K. Burton and M. Post of the CUW Staff.

TABLE OF CONTENTS

1. BACKGROUND

(C) The study of Deployable Undersea Surveillance Systems by the Academy in La Jolla during the summer of 1967 reinforced the feeling of those involved that there was definitely a place for such systems in support of the Navy's missions. The concept of a family of systems that would provide the option of establishing, maintaining, and withdrawing surveillance of any ocean area in the world without undue cost, time lag or political embarrassment appeared quite feasible.

(C) The time spent defining the characteristics of deployable undersea surveillance systems led to a conviction that they must possess certain unique characteristics; namely, they must be capable of being installed in a day to a week, they must remain useful for one to six months, their perishable parts must be easily replaced, and their sophisticated portions (signal processing, communications, etc.) must be able to be easily moved.

(C) A major conclusion of the study was that a small number of types of deployable systems would provide surveillance in the majority of the world's undersea environments. However, there are several operational and environmental constraints of overriding importance in system design, such as the nature of the target and the acoustical characteristics of the undersea area. Two system types emerged which offered the most promise of functioning well within the constraints and provided the most general applicability to the many naval situations considered. These were:

(1) A system of concentrated receiving elements with gain so that the refracted surface-reflected path (RSR) may be utilized in order to achieve long range (over 100 miles) detections.

(2) A system of dispersed low-gain receiving elements installed in large numbers with closely coordinated analysis of all outputs in order to deal with the relatively short (less than 30 miles) detection ranges associated with direct sound paths.

(C) In view of the need for covert operation in many situations, the study members felt that the two system types should be designed primarily to operate effectively in the passive mode. The concentrated type, however, was also conceived of as having an active operation capability in order to provide fine-scale target localization and to insure detection even when a target chooses to run quietly for prolonged periods. The elements of the dispersed system were visualized as linked to the central processing station either by cable or by radio as dictated by local circumstances. Thus, two distinct variants of the dispersed systems were implied as well as the possibility of a purely passive version of a passive-active system. The combination of these systems and their variations with each other and with general purpose and fixed surveillance systems were felt to assure effective coverage in a large part of the world's oceans.

(C) The first of the major recommendations of the summer study dealt with the need for bringing deployable surveillance systems into early use. It was concluded that technology is now ready to produce a first generation of such systems over the coming five years and that the Navy should move quickly into the development of the basic system types.

(C) The Follow-Up Panel's effort was directed towards defining the characteristics of the various systems recommended by the summer study and refining differences so that a minimum number of systems would find the widest possible application. As a result three letter-type interim reports have been forwarded to the Navy (OP 71) summarizing the characteristics of the three basic types of deployable systems in their advanced form as well as in a first generation configuration. This report includes the information contained in the interim reports as well as additional material developed by the Panel in their effort to establish the feasibility of a family of systems designed to provide the Navy with flexible tools for undersea surveillance.

2. DISCUSSION

(C) The desirable characteristics of the various deployable systems which developed during the summer study were further developed by the Panel. This was done in a manner which, while keeping in mind the present state of technology, conceived a first generation of systems so configured as to incorporate features consistent with those envisaged for the more advanced systems. Thus a true evolution of deployable surveillance systems is possible, with the later versions building on the experience gained within the particular technology embodied in the early systems. The aim has been to recommend basic system types for first generation systems which could be developed soon (within two or three years) into (not necessarily fully) engineered systems for naval use. These are described as far as possible in terms of sub-system or component characteristics.

(C) The characteristics of the recommended first generation systems are summarized in Tables I - III along with current Navy research and development activity which is pertinent to these systems. They have been chosen with two objectives foremost:

(1) Provide capability for surveillance against existing large numbers of moderately noisy nuclear and diesel powered submarines.

(2) Employ configurations which ensure easy evolution toward features needed to provide surveillance against much quieter submarines.

In order to guide the direction of early efforts, the characteristics of the advanced systems recommended by the summer study are also included.

2.1 DISPERSED BUOY SYSTEM

(C) Table I* treats this system in detail. Each unit consists generally of a surface buoy supporting hydrophones — a pair in the case of the first generation, and an array for the advanced system. The buoy can be moored in depths from 30 to 2000 fathoms, with the hydrophones suspended

*Page 15

at a selectable depth. The signal processing would rely on both broad-band correlation and spectrum analysis of a large number of channels. Communication would be by separate radio link from each buoy. A useful life of at least 90 days is indicated with the buoys considered expendable. Figure I illustrates the first generation system.

(C) There has been considerable activity in systems which have aspects which are adaptable to the concept of the first generation system as described in Table I. The moored sonobuoy system, in particular, contains a number of such features. Because of this potential for drawing extensively on existing technology and components, the dispersed buoy system is considered as being the closest to fruition of the three basic deployable systems.

2.2 DISTRIBUTED CABLE-CONNECTED SYSTEM

(C) This system is described in Table II*. A bottomed cable laid in water as deep as 2500 fathoms serves to connect the sensors which would be hydrophone pairs in the first generation and vertical arrays of 10 - 30 hydrophones in the advanced version. The cable would be connected to a surface or submarine buoy or direct, to shore. Communications to the central processing station could be from the buoy via cable to surface ships or submarines, via radio link to surface ships, aircraft, or shore stations or via acoustic link to submarines (for advanced system only). The signal processing would include correlation techniques and off-line spectrum analysis. A system life of three months to one year is indicated. The general concept of the first generation system is illustrated in Figure II.

(C) Because of the long lead-time involved in the development of an operative system of the cable-connected type, particularly the design and packaging of a cable system appropriate to this problem, the necessary effort will need to be initiated at once if the projected requirements for surveillance of the near-future threat are to be met in waters of moderate to shallow depth.

2.3 CONCENTRATED PASSIVE-ACTIVE SYSTEM

(C) The details of this system are covered in Table III**. Figure III shows the first generation version of the system and several alternative concepts for deployment vehicles. A rigid structure roughly 500 feet

*Page 18 **Page 21

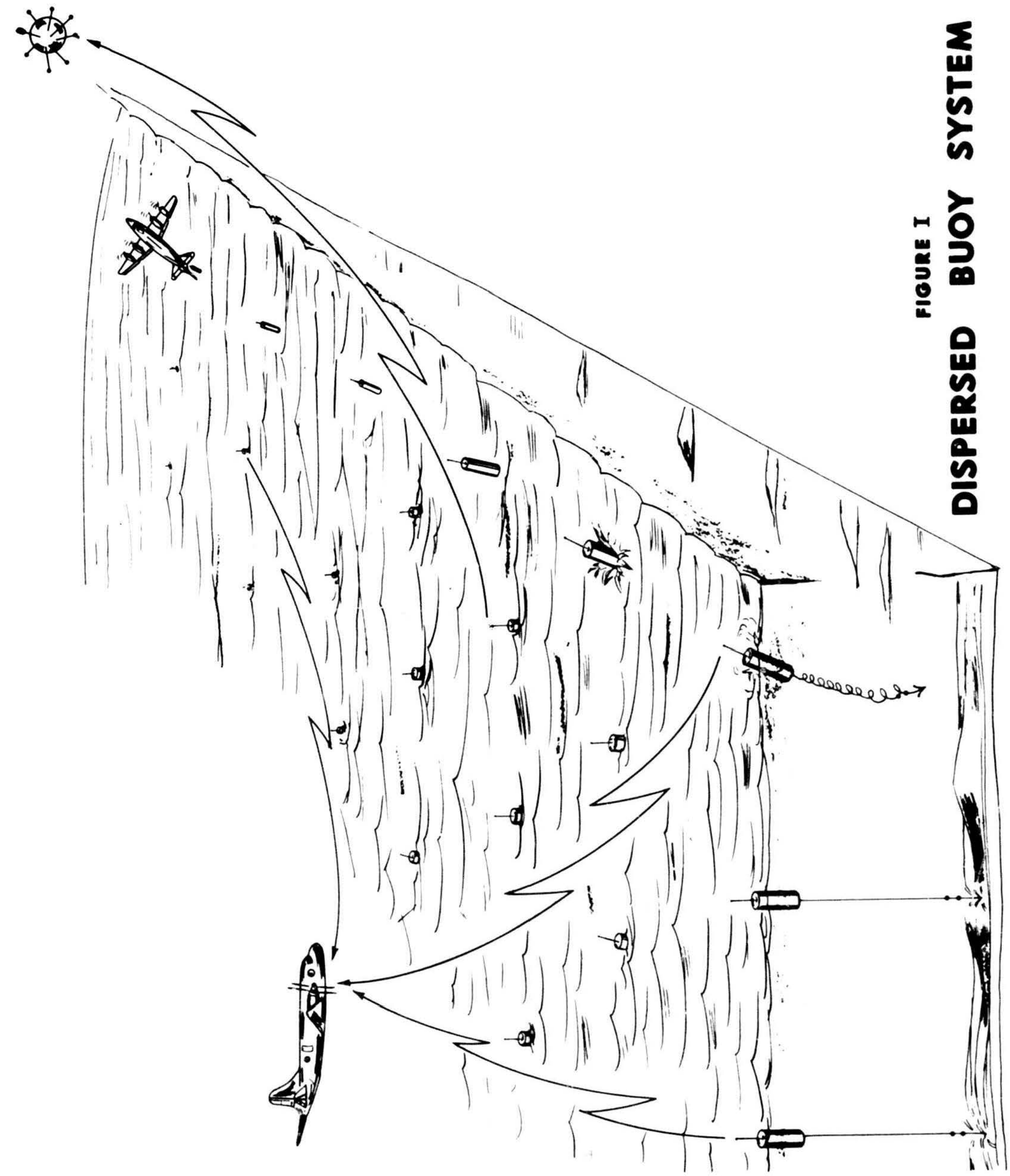

FIGURE I
DISPERSED BUOY SYSTEM

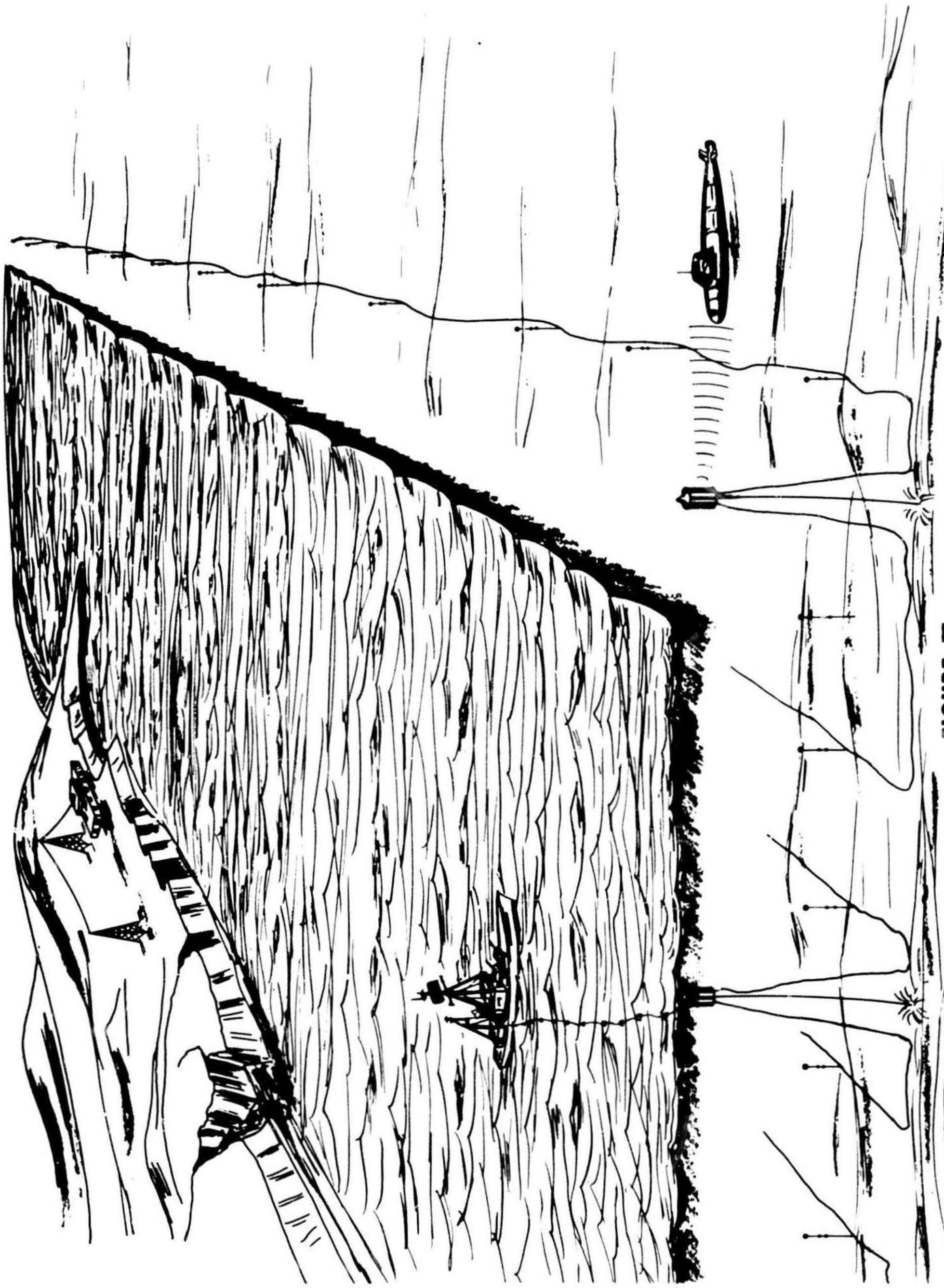

FIGURE II
DISTRIBUTED CABLE-LINKED SYSTEM

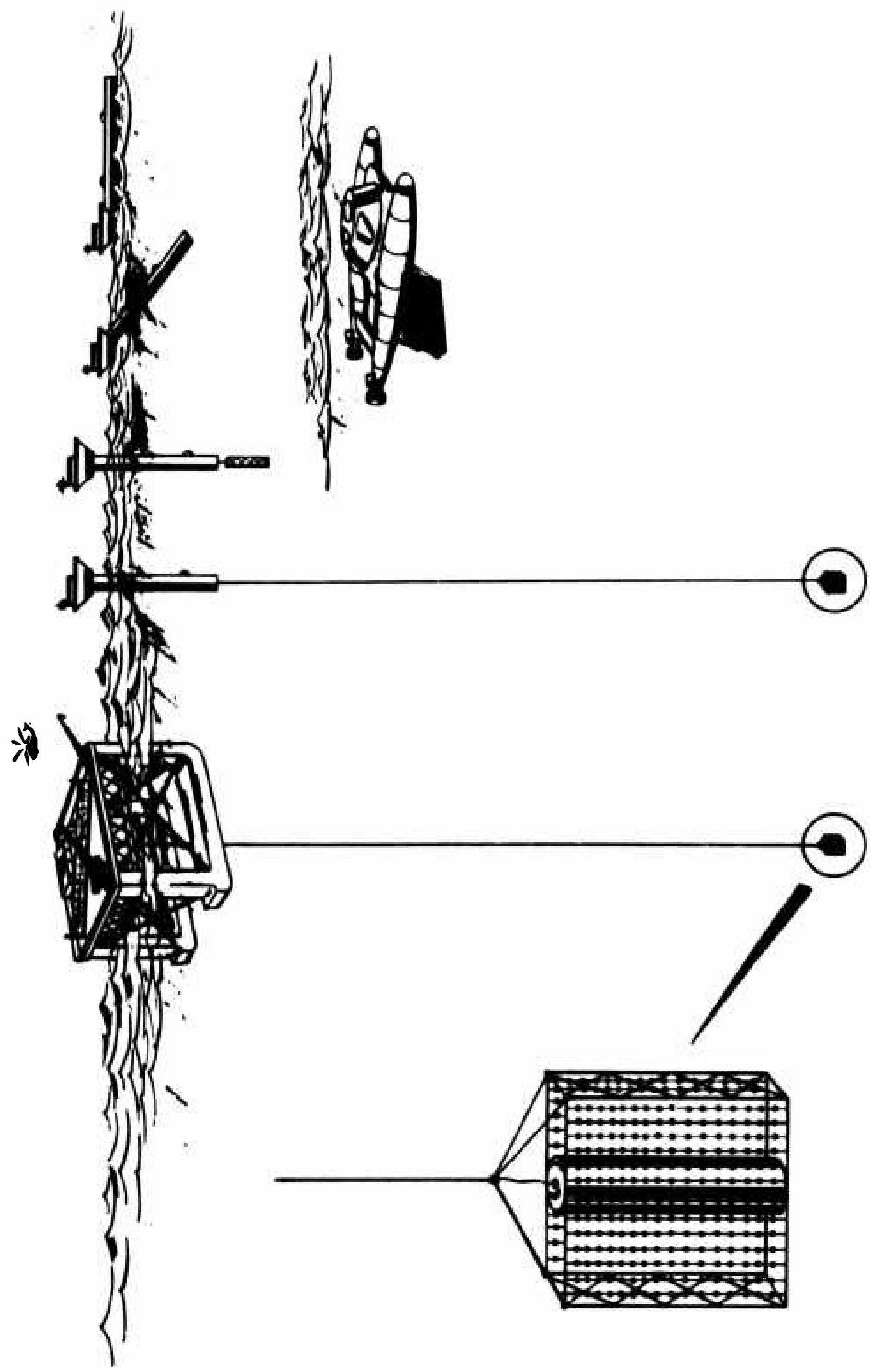

FIGURE III

CONCENTRATED PASSIVE-ACTIVE SYSTEM

wide and 450 feet high supports the passive array which consists of 60 to 100 strings of hydrophones with 28 elements per string (7 groups each with 4 hydrophone elements per string). The active transducer would have a source level of 140db // 1μb for the first generation system (145-155 for the advanced system) at 400-600 Hz. The beamforming would be with two selectable vertical analog beams feeding azimuthal beamformers which incorporate at least one steerable null. Time processing would include power detection and spectrum analysis in the passive section with multichannel cross-correlation in the active section. For the display, computer aided tracking and decision programs would be utilized.

(C) The first generation of a deployable passive-active surveillance can best be considered as developing from an extension of the present RSR program. The Panel feels that this program should be accelerated, particularly with respect to achieving a significant capability in the passive mode of operation. A primary goal should be the construction of a complete system which can be employed in realistic operational situations as well as for the measurement of environmental and acoustical parameters. Such information will be invaluable in determining the design details and projected performance of the succeeding first generation and advanced systems.

2.4 RESEARCH AND DEVELOPMENT PROGRAMS REQUIRED FOR OPTIMIZING THE ADVANCED SYSTEMS

(C) An early capability for undersea surveillance can certainly be developed with the first generation of deployable systems by applying existing engineering developments and conducting environmental surveys to assure optimum use particular specific locations. However, the realization of the full potential of these types of systems with the characteristics as detailed under "Advanced Systems" in Tables I through III is strongly dependent on certain supporting in-depth studies and development work so that an adequate base of technology is ensured.

(C) The discussion in this section is organized to cover the research and development required for the three basic types of systems. In addition, a fourth type of system is covered. This is the so-called intermediate system which would find application in environments which would not normally support RSR propagation but which, because

of reasonably good bottom reflectivity, would allow propagation by multiple bottom-reflected paths.

(C) 2.4.1 For the dispersed buoy system a complete systems study should be undertaken to determine the cost effectiveness of a deep small-array system (relative to, for example, a simpler shallow-hydrophone system) for bottom limited (non RSR) propagation. This study should be done concurrently with the design, construction, and testing of the first generation system so that the results of the systems studies, the environmental measurements, and the engineering studies can be channeled to assist the development of the advanced system. The following outputs of the study should be sought:

- Array Design
- Array Depth
- Processing (Broad-band, Spectrum Analysis)
- Overall Data Processing Requirements
- Utility of Active Option

(C) As such studies progress, concurrent engineering studies (e.g., taut vs. slack wire mooring) and environmental measurements (e.g., noise characteristics of bottom limited regions; propagation characteristics where bottom reflectivity is involved) should also be carried out.

(C) The object of the environmental measurements and studies should be the improvement of shallow water (< 100 fms) and bottom limited deeper water (100-2000 fms) propagation models. An iterative process should result with the output from engineering and environmental studies being fed back into system studies. These, in turn, will suggest further engineering and environmental studies (e.g., propagation fluctuations; statistics of surface effects; in-buoy vs. remote processing; real time vs. compressed time (delayed) processing). Communications engineering of the overall buoy monitoring problem (e.g., satellite relay; a/c relay to ship; direct a/c monitoring, etc.) will have to be studied.

(C) The applicability of the techniques considered by the summer study and the Panel will, in practice, be dependent on the requirements developed for the overall system. These requirements, however, cannot properly exploit technology without adequate validated exploration of

an appropriate range of ideas. The engineering studies should develop costs which can be used in the systems study.

(C) 2.4.2 The distributed cable linked system will require system studies directed at the questions of array design, array and hydrophone spacing, types of processing, data handling requirements, and active operation considerations in much the same manner as the distributed buoy systems.

(C) Engineering investigations will, in addition, have to consider the cable system design; packaging and laying; processing at arrays versus processing at terminal point; potential of acoustic link — or E/M buoy — versus direct coupling, and the questions of power sources for detectors, repeaters, and the terminal.

(C) Environmental measurements should include noise characteristics of candidate areas, bottom loss and coherence effects, overall propagation statistics, and deep currents and their variations — both within an area and with time. Some of these measurements should be made (or ways of making them developed) not only to help system design but to aid decisions on where and when to lay a system (e.g., environmental data required for system use as well as system design).

(C) 2.4.3 The concentrated passive-active system will require systems studies of the array configuration, the types of processing and related data handling problems, the modes of operation (active versus passive), waveform type, ping clusters/tracking procedures, etc. Optimum array depths for different modes of operation or tactical situations will also require study.

(C) Engineering investigations will have to consider the development of large transducers, the design of large receiving arrays and their deployment, suspension systems and their winches, the minimization of flow induced noise and strumming in the array and the design of support platforms for both surfaced and submerged applications. Cable design should receive attention as well as display techniques, adaptive beamforming applications, position holding for both array and platform, and detection and classification via complex amplitude spectrum analysis (e.g., phase between harmonics).

(C) Environmental measurements should be made which identify the causative factors in the noise backgrounds in order that predictions might be made. The detailed structure of the noise spectrum, fluctuations in noise levels, transients, and directionality of ambient noise should all be evaluated for candidate areas. Reverberation will have to be evaluated: its coherence, energy levels and the tails of spectral spread. Information to support the development of predictive models will be needed as well as measurements on the energy distribution in propagation modes (e.g., bottom bounce to RRR from sloping shelf), time coherence of bottom bounce, and wave front distortion and stability. As in the case of other systems, deep currents should be measured.

(C) 2.4.4 An intermediate system was considered by the summer study as possibly necessary to provide surveillance in non-RSR regions under circumstances in which bottom reflection losses may be small. This system was envisaged as a longer term development which would have to be thoroughly investigated both as to characteristics and need. A systems analysis to determine whether a separate system for this type of propagation is warranted and might be cost-effective is required after the environmental measurements in these regions have been obtained. Effectiveness of such a specially designed system should be assessed relative to that obtainable by using either a dispersed system used in better conditions than it was designed for or a concentrated system used sub-optimally. Such an analysis will need as its starting point additional documentation of bottom bounce losses in operationally significant areas of intermediate depth.

3. CONCLUSIONS

(C) Continued review of the 1967 summer study concepts through the past year and the process of relating these to existing R&D programs and changing conditions has not led to any feeling that the conclusions presented in Volume I need to be significantly modified at this time. Urgency in obtaining operational experience still exists as does the need for obtaining this with both widely distributed and strongly concentrated systems to provide practical starting points for further development of this useful category of systems.

(C) The state of development of the moored sonobuoy system, when combined with other sonobuoy development, is such as to provide a technological base which, with a moderate additional investment, would result in the earliest availability of an operational deployable system. This system would meet many of the Panel recommendations for a distributed buoy system for limited area coverage in regions of intermediate to poor sound propagation.

(C) The summer study recommended as a second dispersed type a ship-laid cable connected deployable system. Because development of an operative system of this type will take longer than for the buoy system, effort should be initiated as soon as possible in order to meet fully the requirements for surveillance in moderate to shallow water against the near future threat.

(C) The concentrated passive-active system was the third basic type of system recommended by the summer study. The existing RSR program may provide an adequate starting point for development of a deployable system in this category. Additional emphasis, however, should be given to the passive capability of such a system.

4. RECOMMENDATIONS

4.1 SYSTEM DEVELOPMENT RECOMMENDATIONS

(C) The Panel recommendations for early development of deployable surveillance systems are:

1. The Panel strongly endorses the recommendation of the summer study that a deployable undersea surveillance system be brought into being at an early date. Thus will the Navy be provided with a flexible tool to meet their responsibilities in this regard.

2. Develop, on a priority basis, to the stage of a prototype system, a dispersed buoy system of the moored passive type with the characteristics listed in Table I using the technology accumulated via the moored sonobuoy program and other related programs.

3. Develop to the stage of a prototype, a simple, basically passive, distributed, cable-connected surveillance system with the characteristics listed in Table II.

4. Accelerate the current RSR program with additional emphasis on a passive capability. The program should include both construction and use of a research system for measurement (environmental and acoustical) and also development of equipment that, while not necessarily engineered for service use, can be taken to sea and used by laboratory personnel in realistic situations. The characteristics of the recommended system are listed in Table III.

5. Use these prototype systems in appropriate operational situations and exercises with the fleet to assess their effectiveness and to gather data for design of later systems.

4.2 EFFORT RECOMMENDED TO ENSURE AN ADEQUATE BASE OF INFORMATION AND TECHNOLOGY

(U) Studies and exploratory development work should be carried out now to allow planning of future development of the follow-on systems. Particular areas of work and examples of tasks which should be undertaken are discussed in Section 2.4 and listed in Table IV* below as well as in Volumes I and II of the 1967 CUW summer study report.

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*Page 25

TABLE I —— DISPERSED BUOY SYSTEM

	Current Activity	First Generation System	Advanced System
I. System Characteristics			
A. Sensor Components			
1. Support Structu[re]	Moored Sonobuoy System (MSS) under development employs explosive anchor & is designed for operation in water depths of 80 to 3000 fms. Emphasis is on deep water operations using a slack line mooring with hydrophone depth fixed at 200' (SCARAB). Current SCARAB contract will provide additional sea tests beginning Sept. 1968 in order to demonstrate feasibility of mooring & critical components. No FY-69 funding for complete buoy models. Some tests have been made with taut wire (LOLITA) but have been dropped due to funding limitations. Possible completion 1 1/2 year after contract date. The use of different array configurations at varying depths is under study for next generation sonobuoy systems (DEEP JULIE, ATSS, BASS). The DEEP JULIE program has demonstrated experimental techniques for system would require study & test, particularly on the effect of a slack moor in self-noise & array gain. Use of taut line may be dictated. Possible answers by 1970 if funds are available. Nothing has been done on slack line mooring of arrays.	Moored surface buoy. Hydrophones suspended by cable from buoy. Mooring depth range 30 - 2000fm. Hydrophone depth selectable to be either near surface or near bottom.	Moored surface buoy supporting selectable depth array. Mooring depth range 30 - 2000 fm.
2. Sensor Elements	Development has been limited to single omni-directional hydrophones. The bandwidth is in excess of 20 - 2000 Hz. Available now. The use of directional hydrophones (DIFAR) is under consideration. Under a mine development program (CAPTOR) there has been experimental work with moored systems using vertical omni-directional hydrophone pairs with separations of about 10'. There is no surface float or radio link & hydrophones are best at about 1000' depth. Shallow water operation (50 fms) is also planned. Bandwidth is about 130-4000 Hz.	Vertical pairs of omni-directional hydrophones. Bandwidth 20 - 2000 Hz.	Array of 10 - 50 hydrophones. Bandwidth 20 - 2000 Hz.
B. Active Capability	Effort has been limited to proposals & studies considering separate sound sources such as air dropped explosives. A moored ATSSS has been studied & some related experiments have been carried out under CAPTOR.	None.	Should be considered either as part of system or by an additional (independent) system
C. Signal Processing	Real-time spectral analysis 0.2 Hz B.W. 10 to 300 Hz (in aircraft). Available now via [illegible] program. Real-time correlation - 100 to 500 Hz (in aircraft) with hydrophone spacing of 350 - 700 ft. Available now via CODAR system. NUTMEG program provided experimental, airborne 50:1 compressed time spectral analysis equipment for 10-300 Hz band with an effective resolution of 0.2 Hz. System records continuously & plays back 50:1 on R.F. Real-time spectral analysis 10-2400 Hz under development under DIFAR and VSX programs. DIFAR will perform analysis in selectable 300 Hz bands at 0.25 Hz analysis bandwidth or 80-2400 Hz at 2 Hz bandwidth, while VSX processor will cover complete band simultaneously with percentage bandwidth starting at .04 Hz at 8Hz. Both will be available by 1970. There is no effort on compressed time spectral analysis 20-2000 Hz. Present channel bandwidth limited to about 800 Hz at 50:1 time compression. In-buoy spectrum analysis in 10-300 Hz bandwidth has been investigated under SEAWATCH. A processor to fit space available in SCARAB buoy is being built.	Spectrum analysis up to 2000 Hz. Broadband cross-correlation with vertical hydrophone pair (1-2 kHz) + local (in-buoy) processing to produce correlator outputs for transmission. In-buoy broadband correlation could be dispensed with in initial system design if incorporation would impose unacceptable delay in early completion of a first generation system. Compressed time recorded transmission on command.	Beam forming at the array. Spectrum analysis and broadband cross-correlation (passive). Echo processing (active). Some or all signal processing in buoy to reduce required transmission bandwidth for large buoy fields. Compressed time recorded transmission of passive information.

TABLE I —— DISPERSED BUOY SYSTEMS (cont'd.)

	Current Activity	First Generation System	Advanced System
C. Signal Processing (continued)	In-aircraft correlation processing in band 15 to 55 Hz at horizontal spacing of about 50' has been demonstrated experimentally (ROFAR). In-buoy processing of a pair of hydrophones has been demonstrated under CAPTOR program. Vertical spacing is 10' and line analysis and subsequent lock-on occurs in 130 to 210 Hz band while cross-correlation analysis covers band 500 to 4000 Hz. Compressed time transmission of raw data for a hydrophone pair over the bandwidth of 20-2000 Hz has not been demonstrated. Current system RF bandwidth limits use to transmission of raw data from one hydrophone over band 10 to 500 Hz plus correlator outputs over complete band. Signal processing associated with multi-element systems have been investigated in exploratory development and advanced development (DEEP JULIE, ATSSS, BASS) but no engineering development has been initiated. Amount of in-buoy processing depends on mode of operation (active or passive) and degree and type of processing (beam forming, cross-correlation, adaptive processing).		
D. Data Linkage	Present system utilizes cable to surface and radio link to aircraft at VHF (162 - 174 MHz). There are 31 radio channels spaced 375 kHz apart with an information bandwidth about 40 kHz. Available now. Satellite relay has been considered under SEAWATCH and simulated in high altitude aircraft tests. No effort at present.	Cable to support platform (buoy) radio from buoy.	Radio to or via aircraft or satellite.
E. Data Processing & Display	Compressed time experimental system is primarily manual at present. One operator can handle six channels in compressed time for initial detection (OCEAN IV). Available now. Computer aided processing being investigated. OCEAN IV data being processed by computer to demonstrate technique (APOJI-R). Automatic line integration and detection demonstrated under PANDORA, APOJI & DIFAR programs. Development under DIFAR II. & VS-ANEW programs. Estimated Completion 1969.	Large numbers of channels (e.g., 200). Computer aided processing desirable to handle data.	Larger number of channels: Computer processing; automatic detection.
F. Power Supply Characteristics	SCARAB battery life goal is 90 days. Demonstrated to 60 days. 90 day capability can be achieved with some relaxation of weight and space. Fuel cells (GE) being procured for test purposes.	Battery adequate to support normal operation for 90 days.	Adequate to support normal operation for 90 days.
G. System Life	Command Destruct Developed Under CASS.	90 days. Self sink or sterilize feature desirable.	≥ 90 days. Self sink or sterilize feature desirable.
1. Reliability	Initial reliability of 90% at 50% confidence specified. Reliability of 80% for full 90 days called for.	75% reliability for 90 days.	75% reliability for 90 days.
2. Vulnerability to Damage	Survival in sea state 8 called for.	Must survive in sea states up to 8.	Must survive in sea states up to 8.
3. Repairability		None. (Not recoverable).	Requires further study. Perhaps recover functioning buoys to replace power packs.
H. Countermeasures Resistance	Some studies on C/M were done under SEAWATCH program. Others are in progress. Studies to be completed by 1969. Command destruct, self destruct, and anti-tamper features. Available.	Low for first generation system.	Not very susceptible to acoustic C/M, except in the vicinity of jamming source. Particularly true in poor propagation areas. (Psuedo-noise r.f. carrier transmission to minimize susceptibility).
I. Other Features	Buoy identification by coded command and identification of RF channel. Radar transponder dropped due to false triggering on side lobes.	A capability for positive means of location essential.	A capability for positive means of location essential.

TABLE I — DISPERSED BUOY SYSTEMS (cont'd)

Page 3 of 3 pages

	Current Activity	First Generation System	Advanced System
II. Environment			
A. Data Required for Development of System	Measurements on directionality of ambient noise in progress under BASS & SOSUS. Estimated completion 1971. Model to show effect of shipping distribution on ambient noise at low frequencies has been prepared by A. D. Little.	None.	Bottom bounce losses at $7^{\circ} - 15^{\circ}$ grazing angle and for mud and mud-sand bottom compositions. Directionality of ambient noise. Reverberation data for active system.
B. Data Necessary for Optimum Deployment System*	Water depth Ambient noise obtainable from: a historical data available b. in situ measurements, development of calibrated sonobuoy completed. c. from (A. D. Little and LRAP models being developed to be completed in 1970 Sound velocity profile data available. Prediction from ASWEPS. In situ measurements by air dropped BT. Sea state data available (not required for MSS).	Sea state, ambient noise, S.V.P., water depth.	Sea state, ambient noise, S.V.P., water depth.
C. Limitations on Use of System	Adaptive beam forming under study (BASS) in an attempt to reduce effect of high density traffic. Estimated complete in 1975. Funding limitations impede progress.	High background noise.	High background noise.
III. Support Aspects			
A. Pre-deployment			
1. Transport	Present MSS design calls for air transportable, less than 350 lb buoy.	System should preferably be lightweight and air transportable.	Must be air transportable in quantity.
2. Positioning	No problem.	Storage at selected air bases and selected ports worldwide.	Storage at selected air bases and selected ports worldwide.
3. Assembly	Current design does not require removable battery package or selectable moorings feature. For shallow water use shorter cable length and consequent weight reduction can readily be incorporated.	Each buoy is a module.	Each buoy should be able to be assembled locally employing removable power package and selectable mooring module. However, cost/effectiveness of modular concept requires further study.
4. Checkout	Present design goal is 7 year shelf life with no pre-deployment check out.	Good shelf life to minimize need for special test equipment and pre-deployment check out of each unit.	Good shelf life to minimize need for special test equipment and pre-deployment check out of each unit.
B. Deployment Vehicle/mechanism	Aircraft deployed version can easily be modified for ship deployment.	Aircraft or ship.	Aircraft, ship or submarine.
C. Monitoring Platform	Present design calls for aircraft monitoring. (Available). Satellite relay has been investigated. Problem is communication bandwidth requiring in-buoy spectral analysis. Aircraft relay to ship or shore. (Available).	Aircraft if possible, but consider relay to a ship or shore if more convenient.	Aircraft, ship or shore via airborne or satellite relay.
D. Recovery Mechanism	Recovery of large packages being investigated; application to MSS or follow-on system not supported by cost studies.	None.	None. Abandon defective buoys and sensors. Perhaps recover functioning buoys to replace power packs. See G 3 above.

* For optimum planning of system configuration. A system of this type is undoubtedly usable as long as the depth of the water is adequate for mooring. Optimum deployment (e.g., spacing of units and hydrophone depths) will depend on knowledge of this data.

TABLE II --- CABLE-LINKED DISTRIBUTED SYSTEM

	Current Activity	First Generation System	Advanced System
1. System Characteristics			
A. System Characteristics			
1. Support Components	Bottom mounted submarine cables in lengths up to several hundred miles have been installed in water depths to 2500 fathoms to connect various sensors (single hydrophones, hydrophone pairs, and arrays) to the bottom with the support structure being only the cable, or in some instances a rigid mast. These techniques are available now from Projects Artemis, Autec, Caesar, MILS, and Trident. Sensors -- hydrophones, hydrophone pairs, vertical arrays, horizontal arrays, etc., have been used in the above named Projects. Hydrophones with bandwidths from 2-2000 Hz with omnidirectional and/or directional patterns are available today from a number of suppliers.	Bottomed cable, up to 100 nmi. in total length, laid in water as deep as 2500 fms. Sensor units buoyed up to as much as 200' above bottom. No support structures apart from cable. 15 sensor units per 100 n.mi. cable (i.e. spaced 7 miles) with repeater at each paired unit. Sensor units to consist of vertical hydrophone pairs with about 20' spacing between individual elements. Horizontal pairs as an option for shallow water. bandwidth 20-2000 Hz.	Bottom cable, up to 200 n.mi. in total length, laid in water as deep as 2500 fms. Vertical masts or buoyed cables supporting vertical linear hydrophone arrays (for deep water use) or vertical hydrophone pairs (for shallow water use). Inter array spacing selectable at 5, 10 or 20 nmi. for deep water system. Pair spacing closer than this for shallow water system (up to 500 hydrophones total). Vertical line arrays to contain 10-30 hydrophones to achieve vertical directivity. Bandwidth 20-2000 Hz.
B. Active Capabilities	No current effort. However, separate sound sources such as explosives and/or projectors are presently available for this application.	None	Active capability desirable to combat target quieting. Feasibility will however depend on availability of low cost, long lived power supplies for sound sources, on results of research and development on active operation of distributed sensor systems, and on information obtained from operation of the first generation system.
C. Data Linkage	Multiple pair, multiple quad, and coaxial repeatered cables for connecting sensors to terminal equipment over distances from a few hundred feet to several hundred miles are available today that will provide a multiplicity of information channels (Projects Artemis, Autec, Caesar and Trident). A new cable data linkage system (SD-C) utilizing a one-inch armorless coaxial cable and a transistorized repeater that will provide a 1.0 MHz bandwidth and be capable of being deployed in deep water (4000 fathoms) in lengths in excess of 3000 miles is being developed by BTL under Project Caesar. First installation planned for FY72.	Easily handled coaxial cable, up to 100 n.mi. total length, with repeaters at each sensor unit (cable and repeater bandwidth 100 kHz), to ship, shore or buoy.* Buoy hard wired to ship or submarine (in latter case, buoy could be submerged), but consider radio link.	Via low cost coaxial cable**- up to 200 nm. total length - with repeaters (bandwidth > 100 kHz) every 5-10 mi. joining all sensors to a shore or floating platform processing station. H.F. acoustic telemetry to submarine, radio to aircraft or ship, and/or radio relay via aircraft or satellite to ship or shore for buoy terminated system.
D. Signal Processing	Real time spectral analysis 0.2 Hz bandwidth over a band 10-300 Hz is available now (Jezebel). Real time correlation over a 100-500 Hz band with hydrophone spacing of 350 to 700 feet is available now (Codar). 50:1 time compressed spectral analysis over a 10 to 300 Hz band with an effective resolution of 0.2 Hz is available from the NUTMEG program. Real time spectral analysis over 10 to 2400 Hz band under development (Difar II). Difar II will perform analysis in selectable 300 Hz bands at 0.25 Hz analysis bandwidth, or an 80 to 2400 Hz band at 2.0 Hz analysis bandwidth. A VSX processor covering the 8 to 2400 Hz band with a percentage bandwidth analysis starting at .04 Hz at 8 Hz is being developed. Both the Difar and VSX processors are expected to be available by 1970.	Frequency multiplexing of analog signals from both hydrophones of pair.* Pre-amplifiers at hydrophone units. Spectrum analysis. Broad band correlation between hydrophone pairs. Capability for acoustic transient detection.	Hydrophone pairs: cross correlate at hydrophone and transmit averaged correlator output for small number of relevant time delays. Transmit raw signal from one hydrophone of each pair for spectrum analysis. Array: beam form (include possible adaptive techniques) broadband correlation, spectrum analysis and transient detection. Trade-off between performing various of these operations before or after cable transmission to be determined based on development of cable technology and system goals.
E. Data Handling	A development model of the APOJI/R equipment with automatic line detection and classification has been built and tested. The APOJI/M multi-beam detection, classification and target accounting is under development and the first model is expected to be delivered by the fourth quarter of FY69. An integrated shore processing equipment for SOSUS is being developed by BTL. This equipment features automatic line detection, signal characterization, target characterization, and target tracking as well as off-line detailed processing (any hour of data in the past four hours manually selected) at 240 times real time. The first development model scheduled for test and field trials in the second quarter of FY72.	Multi-channel automatic processing with detailed off-line analysis of limited number of channels.	Automatic detection of large number of channels combined with off-line detailed signal analysis of limited number of channels. Increased use of multi-channel capability to be incorporated between detection and display; for instance, threshold sensitive auto-tracker to be incorporated with feedback to other units within field in order to enhance their detection capability. Monitoring ship capable of handling more than one cable string or interfacing with other monitoring ships.

*A study should, however, be undertaken to assess the relative advantages and cost-effectiveness of cabling individual sensor units to terminal processor instead of frequency multiplexing analog signals into single coaxial cable.

**The relationship between bandwidth, cable size, and number of hydrophone elements should be examined.

TABLE II --- CABLE-LINKED DISTRIBUTED SYSTEM

	Current Activity	First Generation System	Advanced System
F. Power Supply Characteristics	Shore power cable connected to underwater electronics. Various power transmission techniques available now (Autec, Artemis, Caesar, MILS and Trident).	Cable-fed from ship or shore unless radio link is employed. In latter case power supplied either from large capacity battery in buoy or individual long-life batteries in hydrophone units.	Minimal requirements. Power preamps and cable repeaters. If acoustic telemetry employed, 1-2 kW needed for life of system. (See B Current Activity).
G. Performance Standards			
1. Life, reliability		System life three months to one year. Must insure at least 90% probability that at least 80% of available information channels are operable after 3 months of system operation.	Three months to one year life. Must insure at least 90% probability that at least 80% of available information channels are operable after 3 months of system operation.
2. Vulnerability to damage		Dragging. Deep currents in rough bottom areas. Wave action on buoy may damage cable.	Dragging unless cable buried. Deep currents, particularly in rough bottom areas. Wave action on buoy may damage cable.
3. Repairability	In general underwater equipment and submarine cables in deep water are not easily repairable. In shallow water, underwater units can be retrieved, brought to the surface, repaired and relaid. Cables in shallow water can, in some instances, be repaired or replaced, and if scrubbing action is causing damage, can be immobilized by divers and/or swimmers. Shore and surface platform equipment and instrumentation is accessible for repair at all times.	Divers in shallow water to replace damaged cable sections.	Divers in shallow water to replace damaged cable sections. Future capability of submersible work vehicle for similar repairs in deeper water.
H. Countermeasures resistance	Systems of this type are in general susceptible to the following counter-measures: a. Physical damage to the underwater units and the shore station or surface platform. b. Target quieting (reduction of radiated noise). c. Acoustic jamming and/or spoofing (false targets). With respect to (a) (cutting or destruction of the cable) a technology has been developed whereby cables can be entrenched in the ocean bottom in water depths to 100 fathoms. Major efforts are underway under Projects 24-04 Undersea Surveillance and 24-07 ASW Surveillance to provide counter-countermeasures for (b) and (c) above. Significant results are expected to be available by FY72.	System will be susceptible to cutting or dragging of the cable. Processing station (shore or floating platform) susceptible to diversionary action. System not expected to be very susceptible, except locally, to acoustic c/m because of distributed nature of field and the poor propagation conditions assumed for areas requiring this type of system.	System will be susceptible to cutting or dragging of the cable. Processing station (shore or floating platform) susceptible to diversionary action. System not expected to be very susceptible, except locally, to acoustic c/m because of distributed nature of field and the poor propagation conditions assumed for areas requiring this type of system.
II. Environment			
A. Data Required for Development of System	Considerable acoustic, environmental, and engineering information has been obtained under Projects Artemis, SOSUS, and Trident. These types of data are also being collected under Projects 24-04 Undersea Surveillance, 24-37 ASW Surveillance, and 24-08 Long Range Acoustic Propagation. A model showing the effect of shipping noise on ambient at low frequencies has been developed by ADL. Measurements on the spectrum and directionality of ambient noise are being conducted under the SOSUS and BASS programs.	None	Spectrum and directionality of ambient noise. Combination of short range propagation fluctuation and noise statistics to attack question of cumulative detection probability.
B. Data Required Prior to Deployment of System	Water depth, bottom topography, near-bottom currents ambient noise, propagation, and sea state conditions in area of interest. Methods of obtaining these types of data are generally available now from the above listed Projects and other sources.	Water depth, bottom topography, sound velocity structure, commercial fishing activity.	Water depth, bottom topography, deep currents, sound velocity structure, commercial fishing activity.

TABLE II — CABLE-LINKED DISTRIBUTED SYSTEM

	Current Activity	First Generation System	Advanced System
II. Environment			
C. Limitations on Performance of System	Performance of existing and proposed systems of this type is limited by any one or combinations of the following factors: a. High ambient noise, including interfering noise sources due to weather, shipping and other local noise sources. b. Poor propagation or changing propagation conditions. c. Change in target's mode of operation (quieting). d. High-sea state conditions affecting surface monitoring platform or radio buoy. e. Physical damage to components.	High background noise, extreme sea state action on buoy and tether, and on monitoring platform (if afloat).	High background noise, extreme sea state action on buoy and tether, and on monitoring platform (if afloat).
III. Support Aspects			
A. Pre-Deployment 1. Transport	N/A	1. System components should be air transportable.	System components should be air transportable.
2. Assembly	N/A	2. Prepositioning at major selected ports and air bases. System should be capable of being assembled at local base from pre-packaged modules. Modules should include: a) Hydrophone units, and b) cable lengths plus repeaters. Signal processing equipment should preferably be housed in a single container (e.g., van) for use ashore or on board ship.	Prepositioning at major selected ports and air bases. System should be capable of being assembled at local base from pre-packaged modules. Modules should include: a) hydrophone units, and b) cable lengths plus repeaters. Signal processing equipment should preferably be housed in a single container (e.g., van) for use ashore or on board ship.
3. Checkout	N/A	3. Should be minimal. Modules should have long shelf life.	Regular electronic maintenance at storage location. Modules should have long shelf life.
B. Deployment	N/A	From small naval surface ship (e.g., LST, DE, etc.). Submarine laying of such a system should be considered as an early goal. Electrical monitoring desirable during laying.	From small naval surface ship (e.g., LST, DE, etc.), aircraft (for hydrophone pairs), or submarine (or maybe specially rigged surface ship) with external cable and array dispenser. System should be able to be monitored while being laid in order to check for malfunction.
C. Monitoring Platform	Shore station, surface platform, or buoy relay to aircraft.	Surface ship or shore	Ship, submarine, aircraft, or shore, or relay via aircraft or satellite to ship or shore.
D. Recovery Mechanism	None	None	Abandon, except for cable repair operations. May wish to recover float to save it and electronics.

TABLE III —— CONCENTRATED PASSIVE-ACTIVE SYSTEM

	Current Activity	First Generation System	Advanced System
1. System Characteristics			
A. Sensor Components			
1. Support Structure	BOTTOM MOUNTED. Under Projects ARTEMIS and TRIDENT a number of arrays have been planted on the bottom in deep water and cable connected to shore. For example: a. Fishbowl - is an experimental bottom mounted surveillance sonar with a circular array gimbaled in an outer structure about 30 feet in diameter by 28 feet in height and weighing 15 tons in air. This equipment was successfully installed in 12,500 ft of water 28 miles south of Bermuda. b. Trident Vertical Array - a 300 ft 40-element passive array suspended 100 ft off the bottom (taut wire, buoyancy float at top) in 14,300 ft of water. c. Trident Coherence Array - an 8-element passive array 15 miles in length on the bottom in 14,500 ft of water. d. Artemis Receiving Array - a 210-element passive array distributed over a one-mile square area on Plantagent Bank (Bermuda) at a depth of 3800 to 6000 ft. Each element of the array consists of rigid mast 58' high (buoyed up by a top float) on which 32 hydrophones are mounted and connected so as to form a single output at the base. The array in turn consists of ten lines spaced at appropriate distances apart (running down slope); each line made up of 21 modules. e. Sea Spider - experimental version tested on Blake Plateau. Additional work planned as part of LRAPP. SURFACE SUSPENDED. Under Project TRIDENT the feasibility of handling and suspending large arrays (e.g., 200-ft in diameter by 30 ft high) at sea, under various sea-state conditions from a surface platform was investigated. The results indicated that following platforms could be used: a. Stable ocean-going platforms - Platforms of this type have been built by the off-shore oil well drilling industry and provide a starting point for development. b. A Flip-type vessel - based on existing designs, provided a source/array structure can be developed that will unfold or expand when lowered to the desired operating depth. Versions of the arrays could be experimented with existing craft (FLIP, POP, SPAR). c. Large surface ships - currently installed in the USNS MISSION CAPISTRANO (T-AG 162) is the ARTEMIS Transducer Array approximately 30 ft wide by 50 ft high, weighing about 800,000 pounds and capable of being suspended to depths of 1200 ft. The array is handled through a well in the center of the ship.	Large billboard array (dimensions > 500'w x 450'h.) of 60 hydrophones (2 rows of 30 each). Rigid supporting structure with minimum flow induced platform noise suspended to depths of 5000'* from surface platform.	Large cylindrical array (dimensions of about 500'd x 450'h). Rigid or semi-rigid (unfolding) supporting structure with minimum flow induced platform noise, suspended to depths of 15,000 ft from surface or submerged platform or as an alternate, mounted on cables between or along the legs of large (e.g., sea spider) platform buoyed up from the bottom

* At least 5000'. 15,000' desired, but trade-off study needed to establish most practical depth.

TABLE III — CONCENTRATED PASSIVE-ACTIVE SYSTEM

	Current Activity	First Generation System	Advanced System
1. System Characteristics			
A. Sensor Components			
2. Sensor Elements	Two receiving arrays are to be installed in MISSION CAPISTRANO for use in conjunction with the ARTEMIS source. Each array is 56 ft high by 30 ft wide made up of 48 hydrophones spaced a half-wavelength apart at 400 Hz (6-ft spacing) forming six vertical lines of eight hydrophones each per array. One array will be mounted directly on the source structure, the other will be mounted on stand-offs six feet in front of the source mounted array. All hydrophones in a given array are added in parallel at the array to form a single beam 20 degrees in azimuth and 12 degrees in elevation. Present plans call for cutting another well in the MISSION CAPISTRANO to handle the RSR research equipment. The array for this equipment will be a double billboard array (f, 750 Hz) 16.25' h x 26.0' w x 3.25 d (i.e., ¼ wavelength of time delay is to be added to each element in the forward sector. Each billboard array will consist of 54 omnidirectional hydrophone elements spaced ½ wavelength apart resulting in 9 vertical lines of six hydrophones each (18 lines total). 25 acoustic outputs will be provided consisting of 17 full lines, plus one line with the six individual hydrophone elements as separate outputs, plus one low frequency hydrophone, plus one source monitoring hydrophone. Effective bandwidths will be: 300 - 1200 Hz for the line hydrophones; 10 - 1200 Hz for the low frequency unit; and 500 - 1000 Hz for the source monitoring hydrophone. In addition, five non-acoustic outputs will be provided one each for depth, azimuth, inclination, vertical acceleration and sound velocity.	Two dimensional billboard array) 500'wide x 450' high. 60 strings of 28 elements each: 7 groups each with 4 hydrophones elements per string (7 outputs/string x 60 strings = 420 channels). Additional elements may be interspersed to increase active receiving capability.	Volumetric cylinder (or billboard) array with a cross section of about 500'd. x 450'h. Approximately 100 strings of 28 elements each; 7 groups each with 4 parallel elements connected per string (7 outputs/string x 100 strings = 700 channels). Additional elements may be interspersed to increase active receiving capability.
B. Active Source	Extensive investigations into electro-magnetic, piezo-electric, magnetostrictive and hydroacoustic transducer designs for high power deep ocean applications have been carried out under Projects ARTEMIS AND TRIDENT. The ARTEMIS source now on MISSION CAPISTRANO is capable of providing on-beam acoustic levels at 400 Hz of 146 db/µ CW and 143 dB/µb broadband. The RSR research source will provide an acoustic source level of 128 dB/µb at all depths to 14,000 ft.	140 dB/µb source level at about 400 Hz suspended to depth of 5000'*.	145 - 155 dB/µb source level at about 400 Hz suspended to depths as great as 15,000'.
C. Signal Processing			
1. Beamforming	Analog and digital beamforming techniques available. Investigation of steerable nulls to enhance detection, tracking and classification of targets in the vicinity of interfeering noise sources is being carried out at NEL, MPL, H.L., and USL. MPL has built an experimental null-steering array equip ment that will be tested on board FLIP during FY '69.	Two selectable vertical analog beams from each vertical string feeding two (up and down) multiple azimuthal beamformers. At least one steerable null.	Vertical analog beams from each vertical string feeding multiple azimuthal beamformers. Several steerable nulls.
2. Time Processing			
a. Passive	Power and spectrum analysis in the 10 - 1200 Hz range available now. SOSUS uses real-time constant-resolution spectrum analysis 0.2 Hz width (0 - 150 Hz) for standard analyzers, and 0.67 Hz (0 - 50 Hz) for vernier analyzers. Real-time correlation (0 - 150 Hz) available now Raycor and Codar.	Power detection and spectrum analysis in 30 - 300 Hz band.	Power detection and spectrum analysis in 30 - 300 Hz band.
b. Active	Multi-channel cross-correlation using CW, FM and PRN wave forms available today. Optical beamforming and partial coherent processing available (Project ARTEMIS). Signal processing associated with multi-element systems have been investigated (DEEP J"LIE, ATSSS, BASS) however, no engineering development has been initiated to date.	Multichannel cross correlation using CW, FM and PRN waveforms.	Multichannel cross correlation using CW, FM and PRN waveforms.

* At least 5000'. 15,000' desired, but trade-off study needed to establish most practical depth.

TABLE III — CONCENTRATED PASSIVE-ACTIVE SYSTEM

	Current Activity	First Generation System	Advanced System
1. System Characteristics			
D. Sensor to Signal Processor Link	Cables (multi-core and/or coax) for connecting individual sensors or groups of sensors (hydrophone arrays, etc.) to signal processing equipment from a few feet to many miles are available today. Hard wire and multiplex techniques are currently used to provide a multiplicity of information channels (SOSUS, ARTEMIS, TRIDENT and related programs). Electro-mechanical cables both of the multi-core and coax types capable of supporting the weights of existing array and source designs to depths of 15,000 ft are available from several cable manufacturers.	Cables connecting hydrophone groups to signal processor.	Cables connecting hydrophone groups to signal processor.
E. Data Processing and Display	Development model of a 50 times real-time analyzer built and tested under Project NUTMEG. Computer aided data processing being investigated. Ocean IV data being processed by computer to demonstrate technique (APOTI-II). APOTI/M, a multibeam detection system for SOSUS featuring automatic detection, classification, and target accounting is under development. First model of APOTI/M is scheduled to be delivered in the third quarter of FY'69. The BTL integrated shore processing equipment for SOSUS features automatic line detection, signal characterization, target characterization, and target tracking as well as off-line detailed manual processing. The first development model is scheduled for field trials in the second quarter of FY '72. Currently several contractors and Navy laboratories are studying the application of computers to sonar data processing, with the goal of developing algorithms that will reduce the amount of data the operator must evaluate and process. It is expected that useful results of these experiments and studies will be available for application by FY '71 - '72. Conventional recorders, CRTs, DIMUS, LOFAR and CODAR displays available now. In addition, plotting aids ranging from manual plot tables to sophisticated rear-projection computer driven color displays are available (e.g., Nortronics, Ling-Temco Vought, Beloch Instrument Co., General Precision Instrument). NAVSHIPS is investigating the potential gains of new displays techniques such as color, symbology, and format at a facility established at TRACOR. Currently investigations are planned to assess the utility of color displays vs black and white by FY '70 and color vs symbology by FY '71.	Computer aided tracking and decision programs. Computer aided display techniques. Ping-to-ping tracking, post detection pattern recognition to combine multi-path and multiple ping returns; decision thresholds.	Computer aided tracking and decision programs. Computer aided display techniques. Ping-to-ping tracking, post detection pattern recognition to combine multi-path and multiple ping returns; decision thresholds.
F. Power Supply Characteristics	Under Project TRIDENT a 650 kw SCR transmitter has been developed and was used in conjunction with the half-scale (1500-Hz) acoustic source tests. On USNS MISSION CAPISTRANO four electronic amplifiers, each rated at 1300 kw, are used to drive the ARTEMIS source. These units may be operated singly or in parallel to deliver a maximum power output of 5200 kw. At a 25% conversion efficiency, only one of the amplifiers on MISSION CAPISTRANO will be required to drive the RSR one wavelength (750 Hz) research source to rated acoustic output.	About 4 megawatts supply for projector.	About 10 megawatt supply for projector.

TABLE III — CONCENTRATED PASSIVE-ACTIVE SYSTEM

	Current Activity	First Generation System	Advanced System
I. System Characteristics			
G. System			
1. Reliability	Underwater units of the RSR System have a specific 90% probability that 80% of all channels are operative and in balance for a period of two years. Shipboard demultiplexer, processing equipment, and power equipment has a 95% operational availability for 60 day at-sea periods.	90 days at sea. Hazards to source and array from repeated lowering and re-covering.	Up to 12 months at sea. Hazards to source and array from repeated lowering and recovering.
2. Vulnerability to Damage	Hazards to source and array from repeated lowering and recovery. Cable vibration (strumming) may fatigue the strength member. Surface platform vulnerable to damage from high sea-states, and possible collision.	Hydrophones highly recundant. Cable strumming may be a limitation. Vulnerability of surface platform is critical.	Hydrophones highly redundant. Cable strumming may be a limitation. Vulnerability of surface platform is critical.
3. Repairability	Source-array assembly accessible for repair when hoisted and housed in the well. Surface platform equipment and instrumentation accessible for repair at all times.	Accessible for repair when hoisted. Repairable on station.	Accessible for repair when hoisted. Repairable on station.
4. Survivability	Survive in sea-state #6 with the source-array assembly lowered, and be capable of launching and retrieving the source-array assembly and to operate the system in sea-states up to and including #4.	Survive in sea-states up to #6, operate in sea-states up to #4.	Survive in any sea state, operate in sea-states up to #5.
H. Susceptibility to Countermeasures	Susceptible to acoustic jamming, although active portion of the equipment can minimize the effects.	Susceptible to acoustic jamming, although active system can minimize the effects. Processing system should also be designed for limiting and fast recovery from overload to minimize knock-out time. Null steering capability to provide resistance to jamming.	Susceptible to acoustic jamming, although active system can minimize the effects. Processing system should also be designed for limiting and fast recovery from overload to minimize knock-out time. Null steering capability to provide resistance to jamming.
II. Environmental			
A. Data Required for Development of System	Prior to the establishment of Project 24-07, ASW Surveillance, the major portion of the R&D effort to develop a long range undersea surveillance was executed under Projects ARTEMIS, TRIDENT, and SOSUS. Considerable acoustic and engineering information has accrued under these projects. However, there are still acoustic, environmental, and engineering uncertainties to be resolved prior to the development of the First Generation System. Research programs under Project 24-07 ASW Surveillance, and Project 24-08 LRAPP are investigating propagation, reverberation, ambient noise and target characteristics in support of this program. Estimated completion July 1971.	None	Reverberation background; level and coherence as a function of location and time of the year. Propagation: requires good RSR and RSR conditions. Noise: directionality of ambient, supress platform and suspension noise.
B. Data Necessary for Optimum use of System	Water depth, bottom topography, S.V.P. currents, ambient noise, and the distribution of biological scatterers near surface, or surface scattering.	Water depth, bottom topography, S.V.P., currents, and distribution of biological scatterer near surface or surface scattering.	Water depth, bottom topography, S.V.P., currents, and distribution of biological scatterers near surface or surface scattering.
III. Support Aspects			
A. Deployment Vehicles & Monitoring Platform	USNS MISSION CAPISTRANO. It will be necessary to modify the ship to accommodate the RSR research equipment. In general, this modification consists of locating and constructing a new well and associated structure of a cable traction winch and cable storage drum, overboarding sheaves, etc., to raise and lower the source/array structure to full depth. Estimated completion March 1970.	Low speed, stable platform with dynamic positioning capability.	FLIP type, MOHOLE barge type, or ship with center-well type platform. Stable vehicle with speed in 15 kt range.
B. Operational Support	Ship and target services as necessary to support at-sea experiments and operational exercises.	Aircraft for contact investigation; replenishment of stores and fuel by ship (should be able to accommodate replinishment by helo).	Aircraft (possibly STOL and/or VTOL based on platform) for contact investigation; replenishment of stores and fuel by ship or submarine.

Table IV - IN-DEPTH STUDIES OR DEVELOPMENT EFFORT RECOMMENDED TO ENSURE AN ADEQUATE BASE OF TECHNOLOGY TO SUPPORT THE EVOLUTION OF ADVANCED VERSIONS OF DEPLOYABLE UNDERSEA SURVEILLANCE SYSTEMS

SYSTEM STUDIES		ENGINEERING INVESTIGATIONS	ENVIRONMENTAL MEASUREMENTS
DISPERSED BUOY SYSTEM			
PASSIVE			
Acoustic Environment	Array Depth	Mooring (Taut vs Slack)	Noise Characteristics of Bottom Limited Areas
Tactical Environment -	Outputs: Array Design	In-Buoy Processing vs Remote	Propagation -
Vulnerability to Jamming	Signal Processing	Monitoring Problem -	Bottom Reflections and Effect on Coherence
Tamper Proofing	Overall Data Processing Requirements	Real Time vs Delayed Processing	Shallow Water ($d < \approx 100$ Fm)
Freedom to Moor		Relay (Sat'l't. vs A/C vs Ship vs Shore)	Bottom Limited Deep Water (100 Fm $< d <$ 2000 Fm)
Target		Locating Individual Buoys in Field	Surface Effects
Military Objectives and Requirements			Amplitude Fluctuations
			Prediction of Gross Propagation Conditions (Thermocline, etc.)
		Power Requirements vs Available Sources	Propagation & Noise Statistics -- cumulative problem of detection.
DISTRIBUTED CABLE-LINKED			
PASSIVE			
Acoustic Environment	Array Spacing	Cable System Design	Noise Characteristics
Tactical Environment	Outputs: Array Design	Array Packaging and Laying	Bottom Loss & Coherence Effects - Overall Propagation Statistics
Target	Types of Processing	Processing at Arrays vs. at Central Station	Bottom Currents, Topography (variation of currents in shelf areas) (spot checks of significant regions)
Military Objectives & Requirements	Data Handling	Cable Output - Acoustic Link E/M Buoy Direct Coupling (incl. Submarine)	
ACTIVE CONSIDERATIONS			
Need, Relative to Target Quieting & Cost		Powering - Detectors (Passive & Active) Repeators Terminal	
CONCENTRATED PASSIVE-ACTIVE			
PASSIVE			
Acoustic Environment	Array Design	Large Receiving Array - Design, Deployment Suspension	Noise Characteristics -
Tactical Environment	Outputs: Types of Processing	Support Platform (Surface, Submerged)	Fine Scale Directionality
Typical Target Characteristics	Data Handling	Flow Induced Noise, Strumming	Spectral Density and its Fluctuations
Military Objectives and Requirements		Large Transducer Development	Causative Factors of Background Transients
			Spatial Coherence
ACTIVE CONSIDERATIONS		Cable Design	Reverberation Characteristics
Mode of Operation -	Array Design	Adaptive Beamforming	Coherence
Active vs Passive	Outputs: Types of Processing	Detection and Recognition via Complex Spectrum Analysis (e.g., phase relations between Harmonics)	Energy Levels
Waveform Types (PRN, FM, CW)	Data Handling	Platform and Array Position Holding	Tails of Spectral Spread
Ping Clusters - Tracking Procedures	+Power Requirements	Display Techniques	Propagation, Predictive Models -
Optimum Depths			Energy Distribution in Propagation Modes (e.g., Bottom Reflection - RRR)
			Temporal and Spatial Coherence
			Wavefront Distortion and Stability
			Deep Water Currents
			Topographic Shadowing

APPENDIX

CORRESPONDENCE BETWEEN THE NAVY DEPARTMENT AND THE NATIONAL ACADEMY OF SCIENCES RELATING TO THE DEVELOPMENT OF THE FOLLOW-UP PANEL OF THE OCEAN SURVEILLANCE STUDY

COPY

27 September 1967

Dear Dr. Shea:

As the result of the Committee on Undersea Warfare 1967 Summer Study on Deployable Undersea Surveillance Systems, the Navy will receive a wide range of recommendations regarding undersea surveillance system research and development, all the way from efforts in basic research to operational systems development. From discussions I have had with you and the briefings I received on the Summer Study conclusions and recommendations, it is clear to me that it is necessary to retain a panel of selected members of the study group to work with designated Navy representatives in order to determine ways and means to implement worthwhile study recommendations.

Specifically, this joint panel should relate the 1967 Summer Study conclusions and recommendations to the present Navy Undersea Surveillance Research and Development Program, and then provide practical recommendations for redirection of current efforts and/or the formulation of new efforts in the overall program. As a practical matter, panel recommendations for FY 1966 and FY 1969 generally must be limited to those which can be accommodated within the currently programmed expenditures for these years. On the other hand, recommendations for FY 1970 and subsequent years need not necessarily be so restricted. It would be particularly helpful if the panel recommendations were available to me by January 1968 in order that they might be used to assist in formulation of our FY 1970 ASW R&D Program and its supporting budget.

If you agree to forming such a panel, I will provide Captain J. L. Wolf, Head of the Ocean Surveillance Branch (Op-715), to work with the panel and serve as the principal Navy point of contact. Other Navy representatives on the panel will be Mr. Ben Rosenberg, Assistant Director for Systems Planning, DCNO(D) Technical Analysis and Advisory Group, Mr. L. M. Trietel, Division Engineer, ASW Surveillance System Division, MASWSPO, and whomever the Chief of Naval Research designates for this purpose. In addition, I have asked the Chief of Naval Development and the Director of the Antisubmarine Warfare and Ocean Surveillance Division (Op-32) to provide whatever assistance to the working group as may be necessary to achieve results. They have assured me that they will provide complete support and cooperation to the panel in this important endeavor.

Sincerely yours,

/s/ E. W. Dobie, Jr.

E. W. DOBIE, JR.
Rear Admiral, U. S. Navy

Dr. T. E. Shea
National Research Council
National Academy of Sciences
2101 Constitution Avenue, N. W.
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NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES NATIONAL ACADEMY OF ENGINEERING
2101 Constitution Avenue Washington, D. C. 20418

COMMITTEE ON UNDERSEA WARFARE

March 15, 1968

Captain P. B. Armstrong USN
Director, Undersea and Strategic Warfare
Development Division, OP 71
Office of the Chief of Naval Operations
The Pentagon, Room 5C663
Washington, D. C. 20350

Dear Captain Armstrong:

Discussions with you at our recent meeting have further impressed upon us the vital strategic importance of the Mediterranean. The recent expansion of Russian operations emphasize the urgent need for an early effective undersea surveillance capability in that area. As a consequence, we have given further consideration to the results of our 1967 Summer Study on Deployable Undersea Surveillance Systems and the elaborations of its Follow-Up Panel, in order to make available to you advice specifically aimed at needs in the Mediterranean.

The Committee is of the opinion that in the Mediterranean the dispersed buoy system described in reference (a) and further elaborated in reference (b) would be operationally effective and attractive. Therefore, the Navy should, with all deliberate speed, initiate the necessary engineering development and operational deployment of such a system.

Ref. (a) Deployable Undersea Surveillance Systems, Part I (U). (La Jolla 1967). NRC:CUW:0343. December 1967. SECRET

Ref. (b) Ltr to CAPT P. B. Armstrong from Dr. F. N. Spiess dtd 21 Feb 1968 w/enclosure Report No. I of Follow-Up Panel. CONFIDENTIAL

This recommendation is made in light of the urgent need in that area and in full knowledge of the Navy's present plan for deploying towed flexible arrays. The following considerations are particularly pertinent to the matter:

1. The dispersed buoy field system will complement a surveillance operation initially based on towed flexible arrays. It will enable the Navy more fully to capitalize upon the mobility of aircraft which would launch and monitor the buoys, giving a high speed of deployment and broad area coverage.

2. These above qualities would be especially important in circumstances when surveillance is required in areas not suitable for, or not immediately accessible to, a towed array system. Dispersed systems, in general, have an inherent flexibility which, in environments such as the Mediterranean, permit configurations and deployments tailored to the pecularities of geography (straits, basins, shallows, etc.) and propagation conditions (RSR, RAP, direct path, etc.).

3. An operational dispersed buoy field system can be brought into being with a minimum of delay because the achievements of the moored sonobuoy program now in an advanced stage of development.

If further discussions of the subject would be beneficial, the Panel or the Committee stand ready to be of assistance.

Very truly yours,

/s/ T. E. Shea

TES/r

T. E. Shea
Chairman

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13. ABSTRACT

Part III of a three-part report covering the conclusions and recommendations of a special panel organized to relate the work of the 1967 summer study of deployable surveillance systems to Navy's undersea surveillance research and development programs in order that first generation versions of such systems might be available as soon as possible. Three basic types of systems are recommended and their characteristics defined so that a logical evolution to advanced capability is possible.

The report and the 1967 summer study which it draws upon are an outgrowth of a general survey conducted during the summer of 1966. Part I contains general conclusions and recommendations and Part II the detail studies.

14. KEY WORDS	LINK A		LINK B		LINK C	
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